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ABSTRACT

This guide explains ways in which the computer can be used in the science classroom and laboratory. Further, it suggests many resources that can be tapped to help teachers initiate and improve their own programs. Chapters include: (1) "The Computer as a Tool for Student Inquiry"; (2) "The Computer as a Tool for Teachers"; (3) "The Computer as an Instructor"; (4) "Hardware Recommendations"; and (5) "Glossary." The appendices include examples of commercial microcomputer based laboratory (MBL) products; four MBL activities for earth science, biology, chemistry and physics; sources of MBL products; and an MBL bibliography. (YP)

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A GUIDE TO
COMPUTER USE BY THE SCIENCE TEACHER

A Curriculum Development Project

of the

Project to Increase Mastery of Mathematics and Science

(PIMMS)

and the

Connecticut State Department of Education

October 1987

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A GUIDE TO
COMPUTER USE BY THE SCIENCE TEACHER

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A Curriculum Development Project

of the

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Connecticut State Department of Education

October 1987

HISTORY, GOALS, AND SUPPORT OF PIMMS

The Project to Increase Mastery of Mathematics (PIMM) began in 1979 as a joint effort of a diverse group of volunteers -- individuals from education, business, government, industry, and labor -- to foster greater command, understanding, and appreciation of mathematics by graduates of Connecticut schools. The symbiotic relationship of mathematics and its applications was a pervasive theme of the various PIMM undertakings.

In 1983 the organization broadened its scope to become the Project to Increase Mastery of Mathematics and Science (PIMMS) and at the same time expanded its activities by mounting a Fellowship Program. Notably able Connecticut high school teachers of mathematics and science were invited to study together at Wesleyan in courses and seminars as a prelude to offering consultative assistance on curricular matters to schools requesting such service and to providing workshops to teachers for their professional development.

Now several Fellowship Programs are in operation, extending the concept to middle school and elementary school teachers. A significant value of the Fellowship Programs is found in the colleagueship developed among professionals working in different institutions at varied levels.

Several groups of Fellows are devoting the bulk of their energies to writing projects. The materials they prepare will be disseminated broadly to facilitate the introduction into schools of curricular topics in a number of important fields.

Throughout its growth, PIMMS has continued as a partnership of individuals and organizations. The list of devoted volunteers is too long to be recorded here. Major financial support of PIMMS has been supplied by the Connecticut State Department of Education, the Connecticut Department of Higher Education, the Charles E. Culpeper Foundation, the General Electric Foundation, GTE, Divisions of United Technologies Corporation (Hamilton Standard, Norden Systems, Otis Elevator, Pratt and Whitney Manufacturing, Research Center, Sikorsky Aircraft), and Wesleyan University. Substantial contributions also have been made by the AEtna Life & Casualty Foundation, the Amax Foundation, the Army Research Office, Boehringer Ingelheim, Chesebrough-Ponds, Choate Rosemary Hall, CIGNA, the Connecticut Academy of Science and Engineering, General Signal, the Edward W. Hazen Foundation, Northeast Utilities, Omega Group, Pfizer Inc., Pitney-Bowes, Raymond Engineering, SNET, Stanley Works, Union Carbide Corporation, and Xerox.

All of us who are concerned for high quality education owe a great debt of gratitude to these organizations for their corporate citizenship.

R.A. Rosenbaum
Director, PIMMS

FOREWORD

"The most valuable goal of science education is to give students the opportunity to participate in 'real science'. Real science involves investigations selected and designed by the students using flexible, powerful equipment to study issues that matter to the student and others.

We envision nothing less than a major overhaul of the way science is taught, with heavy emphasis on student use of powerful tools applied to interdisciplinary topics and projects of high interest to students."

Robert F. Tinker

This curriculum project provides science teachers with the authors' perspectives, teaching techniques, and insights on the use of computers in science education. A GUIDE TO COMPUTER USE BY THE SCIENCE TEACHER features the role of the microcomputer as an investigative science tool. It also includes sample student laboratory activities involving the microcomputer-based laboratory and a comprehensive listing of available microcomputer-based laboratory products. In future editions we plan to create new student laboratory activities, to update the appendices, and to add new sections (robotics, data networking via modems, interactive video) as new educational technologies emerge.

We earnestly solicit the comments of users of this material. Please send your suggestions for improvement of subsequent editions to:

Robert Shackleton
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Reference in this volume to certain commercial hardware and software reflects the authors' judgments, and does not constitute endorsement or criticism by PIMMS or the Connecticut State Department of Education.

PREFACE

The past century has seen many efforts to change the content and teaching methodologies that structure the ways in which we attempt to provide interesting and effective science programs. The last few decades in particular have seen major philosophical changes that have led teachers to alter the content of their courses from an emphasis on the applications or technologies of science to a concentration on its underlying concepts and principles.

Now we find ourselves at a time when the emphasis is changing again. A renewed interest in the technologies of science is increasingly finding its way into the classroom. There are several reasons for this, but a primary one is the vast growth in the development and use of technology in our culture. It is difficult to name any form of human activity today in which technology does not play an important role. The promises and problems brought to us through technological advances undoubtedly will play significant roles in the classrooms of tomorrow.

The use of technology for teaching has been a bridesmaid for many years. Used here and there in schoolrooms around the world, many teaching technologies have never really taken hold. Programmed instruction and its associated teaching machines, in-school networked computers, and other media approaches never have reached the fulfillment of their promise. In particular, the use of technology in science laboratory instruction has remained essentially static.

With the advent of the microchip, the computer, and solid state probes that are easy to use, we now indeed may find ourselves on the verge of significant change in the application of technology to the art of laboratory instruction. The combination of computers and probes provides the teacher and student with a tool that has three major effects. First, it reduces the tedium involved in the collection of data and allows students to devote more time to an understanding of the concepts involved in the investigation. The structured presentation of data also can allow them to analyze and synthesize the information gained from the activity more efficiently and more effectively. Second, the new technologies open the classroom to a host of different types of investigations that were heretofore difficult or impossible to accomplish. Investigations that involve the electrical activity of the heart, the analysis of voiceprints, or the study of voltage changes in chemical reactions are seldom available in most elementary and secondary schools today. Third, and probably most important, these technologies can unleash student creativity by providing new experiences that generate questions that students themselves can address.

The ability of the computer to act in place of voltmeters, freeze-frame oscilloscopes, thermometers, pH meters, light meters and a host of other laboratory instruments requires that it be viewed not as an expensive tool but rather as the "best buy" in town. This ability makes the computer an essential part of laboratory instruction in elementary and secondary schools just as it already has proved to be essential in the laboratories of colleges, universities, and industries.

This Guide explains ways in which the computer can be used in the science classroom and laboratory. Further, it suggests many resources that can be tapped to help teachers initiate and improve their own programs. The authors are esteemed teachers who have devoted considerable time to learning about and experimenting with microcomputer-based science laboratories. They have used this approach with their students, have conducted many successful workshops for teachers, and stand ready, as do other PIMMS Fellows, to assist teachers who want to enter this new and exciting field.

Sigmund Abeles
Science Consultant
State Department of Education

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INTRODUCTION

The purpose of this booklet is to share with other teachers of science our experiences in the use of the microcomputer so that all may learn from our successes and our failures. We believe that microcomputers have such an important role in today's technological world that their use is essential to providing a top-quality education for present-day and future students.

It is our conviction that the most productive use of the computer in science is as a tool for the acquisition and/or management of information. The computer should be used by students as an investigative tool. The most exciting of these uses for students is the microcomputer-based laboratory (MBL). With MBL, large quantities of data can be quickly collected, organized, stored, graphed, and analysed. Many new questions can be asked and answered which were never before contemplated. MBL presents a new set of laboratory questions to challenge you as well as your students. In fact, you may find that previously uninterested students will begin to respond to science in a positive and enthusiastic way.

Also, we urge all teachers to utilize the potential of the computer as a tool for such information management tasks as word processing, grading, and test preparation.

The PIMMS MBL team offers consultative service and in-service presentations to local school districts and a four-hour Science Awareness Workshop to introduce the Microcomputer-Based Laboratory. Also, copies of this publication are available in printed form for $3.00 per copy or in computer disk form (Applewriter II ProDOS Based) for $2.00. Inquiries about these services and materials should be directed to the PIMMS science coordinator (see Foreword).

In this endeavor we are grateful for the support of the West Hartford, Ledyard, and Newtown school systems, Human Relations Media, and, especially, David Vernier of Vernier Software. We also wish to acknowledge the pioneering efforts and leadership in the field of MBL provided by Robert Tinker and the Technical Educational Research Center.

The Microcomputer-Based Laboratory (MBL)

Introduction to MBL

Rapid, simple, and accurate gathering and analysis of data in laboratory activities represents a fundamental step in the discovery process of science. The ease of data gathering and analysis is of paramount importance if students are to progress through the activity, be comfortable with the laboratory work, and be able to arrive at realistic, rational conclusions. Fortunately, new technology now offers you and your students the opportunity to gather and process data easily.

The microcomputer-based laboratory employs probes or sensors attached to the microcomputer by means of an interface to convert measurements of real world phenomena into digital or binary data. The microcomputer then can store, manipulate, and display or print these data in such forms as graphs or tables. A commercial MBL product typically consists of a disk of computer programs, sensors that attach to the microcomputer and a user's manual. At present the Apple IIe computer supports the greatest variety of MBL software and is the computer most often used for MBL. (See Appendix C for a comprehensive listing of available MBL products.)

The MBL sensors generate one of two types of electrical signals -- digital or analog. A sensor that acts as a switch generates digital data -- that is, the sensor either is or is not sending a signal. (An example is the photogate in which a photosensitive switch either is or is not illuminated by a beam of light.) Such digital data usually can be directed into the computer without modification.

However, most MBL sensors generate analog (continuously changing) electrical signals. The analog signal must be converted into a digital signal before it can be utilized by the microcomputer. If the analog signal is not strong enough or not in the correct voltage range, it must be amplified or adjusted; then it is converted into a digital signal by an analog-to-digital converter (ADC) device and interfaced or sent to the computer. Once the digital data are inside the computer, software can process them and generate output in various forms.

There are two common entry points through which sensors can send data to the microcomputer -- the game port and the expansion slot. The Apple game port was designed primarily for use with game paddles, joy sticks, "mouse" devices, or graphics tablets. However, it is readily adaptable for use with MBL. The port provides three lines for digital input signals (called push buttons or switches) and four lines for analog input

signals (called game paddles). The game paddle lines have the built-in ability to convert the incoming analog signals to digital numerical values called "paddle numbers". Further, the game port has four annunciator lines that can carry digital signals from the computer to external devices. A major advantage of using the game port as the data entry point is reduced cost.

Expansion slots constitute the second common entry point. They are located inside the computer to allow circuitry to be added: MBL circuit boards inserted into these expansion slots can convert analog electrical signals from the sensors into digital signals at a faster rate than through the game port. The advantages of using such external analog-to-digital circuit boards as the entry point to the computer are the increased variety of possible sensors and the tremendous increase in the available number of readings per second.

Types of Interfacing Devices

There are many types of sensors that can detect such physical quanitities as light, temperature, sound, or voltage. These, in turn, are used to determine an even greater number of variables such as heart rate, frequency, distance, velocity, acceleration, pH, EKG, EEG, or pressure.

MBL temperature probe systems consist of temperature sensors (which may be accurately calibrated thermistors), integrated circuits (IC chips), or diodes. All reflect a change in an electrical property (current, voltage, or resistance) as a direct result of a change in temperature. MBL can replace the human observer-recorder for many experimental activities in earth science, biology, chemistry and physics. The advantages are an increase in accuracy of both time and temperature measurements. MBL also enables the gathering of temperature data in difficult locations over long periods of time -- e.g., reading the thermometer inside the freezer section of a refrigerator every 3 minutes for 24 hours. (Appendix A contains examples of commercial MBL products that use temperatue probes.)

MBL use of light probes falls into three categories: 1) light for timing events or the frequency of events (on/off switch), 2) light intensity for substance opacity or distance measurements, and 3) light for energy studies. Light sensors, phototransistors, or photoresistors are connected to the microcomputer through the game port. Such probes provide data collecting opportunities heretofore not available in schools. The major advantages in using light for timing events are the accuracy with which events can be measured and the extremely short time intervals over which events can be measured. The period of a pendulum and the interval of a strobe light are typical examples. Also, determination of your pulse rate, of the distance to a light source using the apparent brightness of

the source, and of solar energy per square meter are activities readily carried out using MBL. (Appendix A contains examples of commercial MBL products that use light probes.)

MBL sound probe systems allow you to detect sound with a microphone, store the information in the computer, and analyze the sound patterns in a number of ways. You can determine the frequency of sound, or "see" your voice print presented graphically on the screen. Another type of sound probe sends out a pulse of ultrasound and measures the time that it takes to be reflected back to the sensor. From this information, the computer can calculate the distance from the sensor to the object that reflected the sound back to the sensor and prepare a graph of this distance as a function of time. (Appendix A contains examples of commercial MBL products that use sound probes.)

Use of MBL in the Classroom

The best use of MBL engages the whole class, is student-centered, and involves an investigative laboratory in which the students are using the computer as a tool for inquiry to "discover" some concept in science that is new to them. Unfortunately not many science teachers have access to the necessary number of computers or the resources to purchase multiple copies of an MBL product.

One approach is to divide the students into groups and to rotate them through different laboratory activities (some of which are MBL) over several laboratory periods. For many MBL devices the time to collect and print the data is very short; thus the entire class may be able to obtain individual data using the same computer within a class period.

Another common approach to the "one computer" situation is a demonstration by the teacher to the class. One large monitor or several regular monitors can be driven by one computer by using phonoplug adapters (see Radio Shack in Appendix C). This will enable an entire class to see the data display clearly. The teacher then can lead the class through a demonstration or an investigation.

With any of these approaches to MBL, the teacher should promote student inquiry. We have found that students will have difficulty focusing on the investigation if they are using the MBL device for the first time. Therefore, it is advisable to teach the students the skill of using the MBL product before they use it to perform an investigation. Often students will have to work in large laboratory groups. Students will get more out of the investigation if the teacher structures the laboratory groups by providing rotating roles for the student members.

Selection Criteria for MBL Products

There are nine questions to ask when evaluating a new MBL product:

1. Is the MBL product a general laboratory tool that can be used in many different investigations? A general laboratory tool is an MBL product that records data, displays data, makes data tables, makes graphs of data, and saves or recalls data at the direction of the user. General laboratory tools are under the control of students and provide them with opportunities to direct their own inquiries.

2. Is the MBL product easy to use ? Do students need to remember anything or is it always obvious what to do next? Can students become "trapped" in a portion of the program with no way to get back to the starting point?

3. Is the hardware durable ? The hardware should be "student proof" and able to withstand the abuse normally suffered by laboratory equipment.

4. Does the MBL product have sufficient documentation that includes student-ready activities and a teacher's guide? Most MBL products do not include fully developed student-ready activities. In a perfect world, teachers would create their own investigations for use with general laboratory tools. In the real world, few teachers have the time to learn about the MBL product and prepare directions for a laboratory exercise that will enable each group of students to work independently.

5. Does the hardware/software read the data accurately ? There is wide variation in accuracy among the various commercial MBL packages that use temperature probes.

6. Are the experiments the MBL product performs part of the science curriculum ? For example, there is an MBL product that measures galvanic skin response only. Not many biology curricula include galvanic skin response.

7. Does the MBL product graph the data as they are taken (real time graphing)? Real time graphing increases student attention to and analysis of the data during the performance of the experiment

8. Can you make a printed copy of the graph? Not all MBL products have this capability without special hardware. It is essential for students to have printed copies of their graphs to submit with their laboratory

reports or to take home to put on their refrigerators. (See Appendix C for products that enable the printing of graphs.)

9. What does the MBL product cost ? Some products are best used as demonstration tools and justify a high unit cost. However, MBL is most effective when used as a tool for student inquiry. This implies the purchase of multiple copies of each type of MBL device that you want to use in the science laboratory. Methods that MBL vendors use to help reduce the costs to schools include:

- marketing the hardware separately from the software with a licensing agreement on the software
- taking a minimalist approach to hardware (avoiding unnecessary use of analog-to-digital converters or interface boxes and using adapter cables instead)
- making the hardware available in kits or giving instructions for their assembly from purchased parts
- developing the MBL packages with in-house staff
- providing updates to the available MBL packages at low cost or no cost (and notifying the users when the package is updated).

Vernier Software currently uses all these approaches.

Benefits and Problems of MBL

There are powerful benefits from MBL. An entire experimental cycle can be completed within the attention span of the student because the time between data acquisition and data analysis/display is brief. For this reason, MBL has great potential for use in investigative science with younger students. Faster data acquisiton also allows students flexibility in repeating experiments, exploring more cases of an experiment, and doing more experiments.

The display of data as they are being taken (real time data display) has many advantages. It can increase attention to what is going on -- for example, while the MBL product is continuously measuring temperatures during a cooling curve experiment, students can watch the sample rather than the thermometers and observe that the crystallization coincides with the temperature "plateau". Students have time to detect an effect and look for its cause. For example, should the temperature drop suddenly during an experiment, students would be alerted

immediately and might discover that a draft had been created from an open window. Using traditional methods, the students might not have detected the data anomaly until they graphed the data after the laboratory session. In addition, research shows that real time graphing increases students' ability to intrepret graphs (Mokros, 1986).

The data display can provide a visual form of communication that for many students is more effective than spoken or written communication. Examples of visual data display include graphs, faster animated molecular movement at higher temperatures, and an animated heart that enlarges when the measured heart rate increases.

Data taken are more dependable than those observed and recorded by students. This increases student success and allows them to concentrate on science rather than on data errors. It permits students to ask more questions and to try to answer them independently.

MBL can be used to take measurements such as instantaneous heart rates, electrocardiograms, or continuous acceleration measurements that were previously unavailable to science students. This allows students to investigate topics that previously only could be discussed.

MBL can increase student motivation toward inquiry by removing much of the tedium of traditional investigative approaches and by taking advantage of the natural affinity that many students have for computers.

Perhaps one of the strongest arguments for the use of MBL in school science classrooms is that college laboratories, research institutions, medical laboratories, and industry now use digital data acquisition devices rather than traditional laboratory methods. The experience with MBL in high school laboratories will prepare students for advanced MBL activities in higher education and in scientific and technical occupations.

There are also problems with MBL.

- Some teachers may be resistant to the use of MBL because of their lack of confidence with computers. Others have the erroneous impression that "the computer does the lab and the student does nothing". Even teachers who are eager to use MBL must have the time to learn how to use it. For some MBL products, the teacher's laboratory preparation time will be increased.

- There are many science departments with no computer access or with limited access.

- Many of the early MBL products supported only a few predetermined experiments; however, recent MBL products are general laboratory tools that provide the student control of the investigation.

- There continues to be a lack of student-ready MBL activities with supporting teacher manuals.

- Beyond anecdotal evidence there is a lack of published data on the impact of MBL on student attitudes and student learning, except for graphing skills.

- The realities of computer access and financial resources tend to decrease the number of laboratory groups and increase the number of students in each laboratory group.

- Many MBL devices use a 16-pin plug that is inserted into a socket inside the computer. The plug is fragile and is easily inserted incorrectly. Unless an MBL package uses the annunciator lines it can be modified to accept the more rugged 9-pin plug in the game port on the back of the computer. Another solution to this problem is to use a game port extender that moves the 16-pin socket to the outside of the computer. (Appendix C lists game port extenders for Apple II computers.)

- The cost of many MBL packages places them out of reach of the typical science department budget. Although many new MBL packages are being developed for use in the middle school science laboratory, products that cost hundreds of dollars lie well beyond the reach of most schools.

MBL use by teachers is in its infancy while MBL product development is still in early childhood. As noted above, there are real problems with developing and implementing an MBL curriculum, but they are more than offset by MBL's performance in gathering and analyzing data and its ability to excite and motivate students when it is used as a tool for inquiry.

Graphing and Curve Fitting

A scientific experiment usually is designed to permit the drawing of conclusions based upon an analysis of data from the experiment. Often, an important step in this process is the production of accurate graphs from the data. By using such graphs students may detect trends in the data and/or determine the mathematical relationship between variables (curve fitting). For example, physics students might determine the amperage, voltage, and length associated with resistors of the same composition and diameter; then they could calculate the resistance and examine a graph of resistance vs length to help determine the relationship.

The computer may be used as a tool to help the student perform these important steps in the inquiry process since MBL hardware and software can serve to provide the data graphs. A good software graphing program for student use should 1) easily accept data from the keyboard or disk file, 2) offer easy plotting procedures, 3) tap the power of the computer by entertaining "what if" questions, 4) provide hard (paper) copies of data tables and graphs via the printer, and 5) permit data manipulation for curve fitting purposes.

An example of a program that meets the criteria for a data graphing program is Graphical Analysis III by Vernier Software (see Appendix C). A sample scenario for student use of the program might involve the analysis of data gathered for an object in free fall:

> The student will have acquired data from experimentation or otherwise and can input the data from the keyboard. The program then will permit (via on-screen dialog) the construction of a distance vs time graph with appropriately labelled axes. The student can make a printed copy of the graph for further study -- which should yield the realization that the behavior is described by a power function (distance proportional to the square of the time).
>
> As an alternative to drawing the best fit curve by hand, the student may use the numerical analysis option in the program to provide a least squares fit with correlation coefficient.

Plotting and data modifications available with this program include a simple Y vs X plot, a plot of Y vs X raised to a positive or negative integral or fractional power, semilog plots, log-log plots, error bars, and the area under a curve (definite integral). The versatility of this program ranges from a simple line or bar graph to a least squares fit of the data. Programs such as this make excellent classroom tools for promoting student inquiry and helping to develop inquiry skills.

Data Bases

A data base is any organized collection of information. The card catalog in a library is an example of a non-computerized data base. In a computerized data base the data are stored magnetically on a disk. We then can use a data base manager program as a tool to perform such functions as adding/deleting/changing data, sorting by type of data, or searching the entire data base for a particular type of data. Data base managers have become indispensable tools in business and scientific research.

In education, a science teacher might be doing a chemistry inventory and could use the data base manager to change the order in which the chemicals are sorted -- arranging them alphabetically or by quantity, cost, reactivity, or hazard level. The computer also makes it possible to search rapidly through records to find specific information (such as all the chlorates in your chemicals inventory) that otherwise would be difficult or time-consuming to find.

A data base manager program can be used with students as a tool for inquiry. The power and flexibility of the computer adds excitement to the process of accessing and manipulating data. Data base managers can help students discover relationships in a way textbooks and other reference materials cannot. While a textbook may provide similar information, students are more likely to appreciate and understand what the textbook has to offer if they discover the relationships for themselves. The searching of data bases should be a discovery process where the student discovers relationships, notes trends, and forms hypotheses.

Use of data bases also may spark a student's interest in a particular subject. The value of a data base package will depend not only on the data base manager and the data base itself but also on the quality of the support materials. Student activities should pose questions that will generate thinking and discussion. Topics should be interesting and appropriate to the curriculum. Also, data bases offer a marvelous opportunity to send students back to books. If a student makes a surprising discovery or draws some interesting conclusions, it should not be left at that; the student should be challenged to investigate the topic further and report findings back to the class. In this way students can develop critical thinking skills while becoming active participants in the learning process. An excellent reference on student use of data base manager programs may be found in the March 1987 issue of Classroom Computer Learning.

Simulations

Simulation programs provide models of natural systems and phenomena. Such programs can provide visual, verbal, or numerical descriptions of what would happen in a natural system if certain conditions were to be changed. Actual systems that are expensive, dangerous, difficult, or too time-consuming to investigate, are prime targets for simulation.

Ecosystems with prey and predator, and operating nuclear reactors are examples of situations that lend themselves to simulation: we can study the consequences of changing the initial number of predators in a model of an ecosystem or of changing the number of fuel cells in a model of a reactor.

Because they encourage students to ask "what if...?" and because they permit relatively simple testing of such questions, simulations can play an important role in science education but they should not replace hands-on experience .

THE COMPUTER AS A TOOL FOR TEACHERS

The computer system with its enormous capacity for storing and manipulating words and numbers offers teachers a tremendous tool for improving classroom learning. Some of the types of programs that allow teachers to tap the potential of the computer for classroom management include word processing, grading programs, graphics creations, test development, spelling and grammar checking, spreadsheets for budget preparation, and data base managers for record-keeping. Such programs -- although not created solely for instruction in science -- can prove useful to teachers by helping improve efficiency in administration of the science classroom, provide for greater instructional flexibility, foster creativity, and save time so that you, the teacher, can concentrate on teaching! Such freedom should result in improved science education and teacher satisfaction.

Word Processing

Carving messages in stone is to paper, pencil, and eraser what the ordinary typewriter is to word processing on a microcomputer. A revolution in the method of creating teacher-produced materials is taking place. Teachers must become part of this revolution which involves using word processing programs to create, edit, revise, store, and print routine daily, weekly, and annual student communications or other documents ranging from laboratory activity sheets, quizzes and tests to stored short stories.

A word processing program accomplishs these tasks via its repertoire of basic operations. Here is a partial list of operations that all word processors include to some degree:

- LOAD a document (FILE) from storage; SAVE a document in storage; begin a NEW document; or insert new material into a document.
- EDIT mode allows you to move text, copy text, erase text, find a word or phrase, or find and replace a word or phrase.
- FORMAT allows you to set letter spacing, start a new page, set margins, center text, insert page headings/footings, number pages, and change print styles.
- PRINT allows you to print the document as well as select the print format parameters.

Here are some of the benefits to teachers from using a word processing program:

- Productivity will increase and the time spent on clerical chores will decrease.
- Correcting errors and rearranging material will become easy.
- The clarity, visual appeal, and organization of printed materials will be improved.
- Multiple copies of materials for students can be prepared from printouts via spirit masters, mimeo, or photocopiers.
- Quizzes and tests can be modified quickly on a period-to-period basis.
- One CAN learn to do all this in a surprisingly short time ... a couple of hours.

Apple Writer II and the word processing portion of AppleWorks are popular programs used extensively by both students and teachers. All word processing programs have their desirable and undesirable features depending on your needs. You should choose one that best fits your needs. The October 1986 issue of A + Magazine contains an extensive review of 40 popular word processing programs.

AppleWorks by APPLE deserves special attention. This program has three components -- a word processor, a data base manager, and a spreadsheet module. Word processing, data base, and spreadsheet documents may be incorporated in a single document. The data base provides for the creation and maintenance of lists (useful for inventories), while the spreadsheet allows for calculations and getting quick responses to data changes in "what if" questions. (A specific use might be in population and demographic studies in biology.) Use of such software holds great potential for science education.

A disk-based tutorial, a 162-page tutorial manual, and a 333-page reference manual combine to provide excellent documentation. There is an extensive network of AppleWorks user groups, a significant core of teachers who are presently using the program, and good support from Apple and secondary-source vendors.

Grade Programs

Grade programs are computer tools that permit storage of student records and calculation of grade averages. Most grade programs will allow you to perform many of the following tasks easily and quickly:

1. Produce a list of all the grades and the current average of any student (helpful for progress reports and grade reports).

2. Produce a list of the grades of all students and the class average for any particular graded activity.

3. Produce a list of current averages of all students.

4. Sort the students according to grade or average for any particular set of grades.

5. Quickly make additions/deletions/corrections to lists or data.

6. Compute averages; drop the lowest grade when computing averages; compute weighted averages

7. Assign letter grades based on a numerical scale.

8. Produce lists of students based on any criteria relevant to the data -- e.g., class rosters or students with assignments outstanding.

9. Alphabetize lists.

10. Print out any of the lists described above.

These programs are useful tools that enable you to give instant updates on student progress (and to help reduce student quibbling about the assignment of grades). They will not save you much time because of the need to enter the data into the computer; however, during the time crunch at the end of a semester you will be able to print out your grades at the touch of a button. The February 1987 issue of Classroom Computer Learning includes an excellent review by Leslie Eiser of 18 grade programs.

Test Creation

Test creation utility programs are essentially specialized data base managers that permit storage of tests as text files. A typical program provides for creating sets of questions broken down into categories chosen by the user. Such storage permits subsequent editing of the document, and

computer selection of test items and/or order of the questions by a random process, if desired. The user also may design an answer sheet and an answer key. Such a program facilitates the preparation of two versions of the same test (when students are going to be seated close to each other) and editing earlier versions of the test without the need to retype the entire test.

At present most of these programs are limited to multiple choice questions at the recall or recognition level; however, with diligent searching (and lots more $$$) more versatile programs may be found. Many teachers prefer to use word processors for the creation of their tests and it is well to note that some of these programs store their files as standard text files which are completely accessible by word processors such as Applewriter or AppleWorks.

Additional Teacher Uses

In addition to word processing, grading, and test preparation, the computer is being used as a tool by many science teachers for such functions as inventory management, budget preparation, and checking the spelling and grammar in word processed documents.

Data bases can be used for keeping an inventory of chemicals, supplies, textbooks, or equipment within the science department. Any tasks which involve an inventory or listed order are possible as data base applications.

Spreadsheet programs are used where calculations are applied to a sets of numbers -- budget preparation and the allocation of funds being two examples. Many teachers who are proficient at using spreadsheets prefer to use such programs for managing student grades.

Spelling checkers are used in conjunction with word processing programs. A spelling checker program usually develops (from your document) a list of words which were not found in its dictionary and gives possible replacements. Good spelling checker programs should be fast, have a dictionary of over 100,000 words, come in both the DOS 3.3 and ProDOS formats (one package), and offer a diversity of options. The user is advised to study such options.

THE COMPUTER AS AN INSTRUCTOR

The computer as an instructor refers to programs that are tutorials, drill and practice, instructional games, or demonstrations. In such programs the software has some science content and either teaches that content or quizzes the student on it. At present there is less emphasis on using the computer as a tool for inquiry.

Tutorials increase students' knowledge in a particular area of science. Programs designed as tutorials involve placing the student in a conversational mode with a computer that has a preprogrammed study plan. Here the goal is to allow each student to progress at a rate directly related to his or her learning capacity. The better tutorials make good use of graphics and, based on the responses from the student, alter the pace, the amount of explanatory detail, and the amount of repetition. Tutorials allow students to review past material or to learn material covered in class during their absence. Students also benefit from the individualization provided by the computer.

Drill and practice programs ask the student a series of questions about a particular topic and then evaluate the student's answers. For example, when a drawing of a human heart appears on the screen, the student might be asked to identify a certain chamber. After receiving several wrong answers the computer will respond with the correct answer and allow the student to go on. The better drill and practice programs also will give and explain the correct answer. Here again, motivation can be stimulated via the computer.

There are some serious pedagogical questions you should ask about a drill and practice program: Does it develop the learning skills as it should? Does it cultivate increased learning compared to the traditional textbook and workbook, or is it merely electronic page-turning?

Instructional games are designed to teach the student through the motivation of competition. A set of rules is given within which the student must function. Many science games are simulations that employ an "adventure game" format. This kind of game often takes a great deal of time for the amount of educational content to be derived from it. The "quiz show" is also used and is a type of game format in which the student is given some basic knowledge before beginning to play the game.

Demonstrations are just that -- demonstrations of natural phenomena or systems in which the outcome is predetermined by the software and computer. Demonstrations do not change their outcomes based on student input. An example of this is the display of the Doppler effect (via the graphics mode) for both an approaching and receding sound source. Demonstrations are most effective when they provide a visual or graphical presentation rather than text alone.

A number of these programs can be used with one computer in a classroom as a class-controlled audio-visual device. These are most useful for simulations, tutorials, or demonstrations where student input affects the outcomes. Such presentations will be sucessful only if all students in the room can clearly see the monitor screen. In order to be successful you should use either a large monitor or a large television receiver with an RF converter. Alternatively, several monitors can be linked to one computer by using splitter cables (one male plug to two female plugs) and monitor signal extension cords (see Radio Shack, Appendix C).

General questions for consideration before purchasing software for use with the computer-as-instructor include:

1. Does it teach what you want to be taught?
2. Does it match the academic level of the student?
3. Is it easy to use?
4. Is it relatively "bug" free?
5. Does it allow for mistakes or is it "dead ended"? -- that is, when you make a mistake can you back up with an ESCAPE (Esc)?
6. Does it tap the power of the computer? Does it do calculations, graphs, animations, etc.?
7. Does it drive the student or is the student the driver?
8. Does it allow for "what if..." ?
9. Does the disk carry with it a site license or must you purchase a program disk for each computer?
10. Can you preview the software prior to purchase?
11. How good is the support documentation?

A description of most educational software programs can be found in a current edition of either of these publications:

Swift's Educational Software Directory
Sterling Swift
7901 South I-85
Austin, TX 78744

The Educational Software Selector
EPIE Institute
Water Mill, NY 11976

HARDWARE

Number and Location of Computers

For investigative MBL science activities there should be one computer for each two students; however, many MBL investigative activities can be carried out successfully with three or four students per station. If computers cannot be provided as suggested above, one computer can be used effectively with 25 students for investigative MBL activities. A single computer can be a powerful teaching tool when used with a large screen monitor for "live" demonstrations and class group experiments as well as for individual or small group projects.

Type of Microcomputers

The microcomputer of choice in most public schools is the Apple IIe. We recommend purchase of Apple IIe or Apple IIGS computers for the following reasons:

- The best MBL systems have been developed for the Apple computer. (See Appendix C for a listing of MBL equipment available for microcomputers.)
- The word processing programs most commonly used in education are Apple computer programs.
- The open architecture of the Apple II series of computers allows outside vendors to develop specialized Apple compatible products such as modems, clocks, memory extenders, accelerators, and devices for the collection and input of data.
- Because of the widespread use of Apple computers, teachers can exchange ideas and methodologies with teachers in other systems or other states.
- There are many Apple user groups throughout the U.S. and foreign countries.
- The Apple IIe computer is well built and can take a fair amount of student and staff use/abuse.
- Repair and service is fairly easy. Parts are readily available both through Apple and secondary vendors. Computer repair shops are not reluctant to work on an Apple since complete documentation is available.
- Apple software is generally "user friendly".

Monitors

When selecting video monitors, take into account the intended use. Monochromatic monitors are best for word processing and the display of text. Color monitors provide a distinct advantage when used with simulation and graphics programs. A mix of both monochromatic and color monitors may be appropriate.

A large (25") red-green-blue (RGB) monitor used in combination with a single computer and small monitor can be a valuable teaching tool for classroom demonstrations. By using a cable which splits the signal for display on both the large monitor and the computer monitor, students can view the large display while the teacher works with the computer and the small monitor. As a secondary benefit, the monitor can be generally available for use with a VCR.

Disk Drives

Each computer used by students should have at least one disk drive and the necessary disk controller interface card. Two disk drives for each computer are desirable. At least three of the computers in the department should have two disk drives because

- the use of spelling checker, data base, and spreadsheet programs (such as AppleWorks) is made less difficult and cumbersome;

- the disk drive is the component most subject to mechanical failure on any computer. A second drive will provide back-up in the event of a problem; the computer still can be used while the "down" drive is being repaired. This is also a good reason for having separate external disk drives.

Hard disk drives which can store 20 megabytes of information are now available for use with the Apple IIe. One 20-megabyte hard disk can store as much information as about 144 floppy disks. (We generally do not recommend hard disk drives for use at the secondary level. Computers need to be moved around for maximum use, and hard disk drives do not take well to such handling.)

Expansion Cards for Apple Computers

Expansion cards go in the expansion slots inside the Apple. They perform such functions as displaying 80 columns of text on the monitor screen, providing additional memory, and accessing peripheral devices such as disk drives, printers, light pens, or modems. To function adequately, an Apple IIe must have a disk controller card and an 80-column card. We recommend that all Apple computers be configured with an extended 80-column text display card which also provides an additional 64 kilobytes of memory for a total of 128K.

Expansion boards increase the amount of memory available for transient storage of information. [See "Two Roads to Memory Expansion" and "Bank Switched Memory", InCider , August 1986. The articles outline methods for increasing the RAM (Random Access Memory) available to you in the computer.] For most purposes at the secondary level, 128K is sufficient and can be achieved with an extended 80-column card at moderate cost.

The choice of a printer interface card is most important. It is essential that students be able to obtain printed copies of their graphs and data. The ease with which this information can be generated is dependent on the printer interface card. (Currently, we recommend Texprint's Print-it. This graphics interface card allows you to print the contents of the screen from any graphics program by simply pushing a button. What you see on the screen you can produce with the printer. Printer interface cards with graphics capability are listed in Appendix C.)

Printers

Dot matrix printers have become popular because of their ability to print graphics, their high print speed, low cost, versatility, and ease of service. If the school system can afford only one all-purpose printer, it should be a dot-matrix printer.

It is desirable to have a printer for each computer. To generate a hard copy of any work or data from a computer without a printer usually requires that the data be saved on a disk, the disk transferred to a computer with a printer, the data loaded into the computer, and then the hard copy printout created.

Many excellent dot-matrix printers are available. If the school system does not have a dependable photocopier, choose a printer that can print on ditto masters.

Expensive alternatives to dot-matrix printers include thermal, daisy wheel, ink jet, and laser printers. Thermal printers are generally not recommended because the replacement cost of thermal-sensitive ribbons is prohibitive. Daisy wheel printers are excellent for final copies of letters or documents but are slower than dot matrix printers and cannot reproduce graphics. Laser printers are expensive but produce an excellent product which comes close to the quality of set type. Laser printers can produce graphics -- the obstacle is cost.

Carts

Each science department computer should have its own mobile cart; if the computer cannot be moved, its effectiveness will be limited. Computers committed to a single science classroom or laboratory are not likely to be used as frequently as mobile equipment. Also, printers and other associated equipment should be attached to mobile work stations or carts.

Modems

The ability to get information from the outside world into the classroom by way of the computer offers many educational opportunities. CompuServe, The Source, Delphi, and CityNet are on-line data base services that are available for a fee. Information services such as DIALOG, BRS, and SDC/ORBIT offer resources as diverse as Books in Print, the Congressional Record, and the complete database of educational materials from Educational Resources Information Center (ERIC). The availibility of data retrieval systems is such that the resources in the classroom can be those of a very formidable library. For more information about these services see The Complete Handbook of Personal Computer Communications by Alfred Glosssbrenner, St. Martin's Press, 1985.

Power Outlets

Power strips with multiple outlets, an on/off switch, and built-in surge protector or circuit breaker should be purchased. The on/off switch on the power strip should be readily accessible and used to reduce wear on the computer power switch. (The power on/off switch is one of the first things to present problems on the Apple II series computer.) Many models of power strips offer merely circuit breaker protection (against too much current) although their packaging promises protection against voltage surges. If you plan to purchase power strips, have the model checked out by the electronics department.

Security

Many devices are available which provide security against theft: steel cables to attach the computer to a solid object; anchor pads to glue the computer to a surface; and security cabinets to physically enclose the computer as well as the drives and monitor. (Andrew Barbour offers a complete discussion of microcomputer security in the April 1986 issue of Electronic Learning.)

Supplies

* Paper - Unlined fan-fold is essential. The quantity needed for each computer will vary but a minimum of two 5000-sheet boxes is suggested.

* Printer ribbons - The printing of graphics generates a lot more wear on the printer ribbon than does the printing of text. Normal usage will require three ribbons per computer per school year. A ribbon may be rejuvenated by spraying it with WD-40 oil: pry off the top of the cartridge and spray the ribbon lightly with WD-40. Cycle the ribbon through so that the other half becomes exposed and again spray it lightly. A re-inking machine is preferable and can be purchased for about $40.

* Blank disks - Back-up copies of software should be kept in a separate, secure location. Furthermore, disks will be needed for storage of student MBL data, word processing files, and public domain programs. Additional disks provide an inexpensive form of insurance.

* Periodicals - To remain current in the field of computers in general and MBL in particular, schools and teachers should subscribe to relevant periodicals. (Appendix D contains a listing of periodicals.)

GLOSSARY

Accelerator: an add-on board which operates at a higher clock speed than the computer and is used in operations which are calculation intensive.

ADC: Analog/Digital Conversion --changing a signal which varies continuously into a signal which is discrete (digital), or vice versa.

Analog: a representation of a physical measurement which shows continuous variation as contrasted to measurements made or displayed in discrete time increments.

Annunciator: a computer line capable of outputting a digital signal.

Back-up: duplicate or copy of any computer program or disk so that information is available should the original be destroyed, damaged, worn out, or stolen.

Binary: existing in either of two states,and thus representable in the base two number system. Example: on/off

Bit: one binary digit (1 or 0), the primary unit of information in the computer. (8 bits = 1 byte)

Boot: the process of starting up the computer by loading instructions.

Byte: a secondary unit of information used in computers. (1 byte = 8 bits)

CAI: Computer Assisted Instruction generally provides practice activities of a repetitious nature. Simulation, tutorial, demonstration, and drill and practice programs usually are included in this category.

Chip: an integrated circuit on a small piece of silicon. A chip may provide memory or circuits for the computer.

Circuit board: an arrangement of electrical circuits on one piece of nonconducting material.

Circuit breaker: a device which will switch off the circuit if there is too great a power draw on the line.

Clock: an integrated circuit in the computer which sends out precise frequency signals. The frequency of the signal controls the number of operations which can be performed in a unit of time.

Computer: an electronic device which is programmed to perform mathematical and logical operations and which can preserve, recover, and process data.

Control characters: letters, numbers, or other keyboard characters used as codes to direct the operation of the CPU or peripheral devices.

Correlation coefficient: a number between -1 and +1 that indicates how closely related two sets of data are. Zero indicates no correlation; a number close to 1 indicates a close relationship.

CPU: the Central Processing Unit controls the overall activity of the computer.

Cursor: visual position indicator (usually a blinking symbol on the video screen) which can be moved up/down and left/right to show the insertion point.

Daisy wheel printer: circular rotating wheel containing letters and characters which prints entire characters at one stroke. The quality of print is the same as that achieved with a typewriter -- i.e., letter quality (LQ).

Data base: collection of factual information which can be retrieved by a computer.

Disk drive, external: disk drive separate from the central processing unit (CPU).

Disk drive, internal: disk drive built into the computer as an integral part of the central processing unit (CPU).

Decimal: number system based on the number ten and used for ordinary computation.

Default: a value or option assigned by the program when one is not specified by the user.

Demonstrations: presentations of natural phenomena or systems in which the outcome is predetermined (here, by the computer program being used).

Digital: presented in discrete bits as opposed to being continuously delivered.

Diode: a solid-state electronic device used to vary current or voltage in a circuit.

DIP: Dual-In-line Package -- an example of which is a plug containing two parallel rows of pins. Permits variation in electronic signals via the setting of switches between the pins in various configurations.

DIP plug: electrical plug which fits into the DIP socket.

Disk: (See floppy disk, hard disk.)

Disk drive: machine which reads or writes data taken from or put on a disk for storage. Such stored information is not lost when the computer is turned off.

Disk drive card: printed circuit board inserted into the computer to allow communication between the computer and the disk drive(s), often located in slot 6 on the Apple.

Document: a unit of work produced with word processing -- e.g., a letter, report, test, or graph.

Documentation: a collection of written descriptions and procedures that provide information and guidance about a program or piece of equipment.

Dot matrix printer: a type of printer that uses elements in a rectangular arrangement of pins (matrix of dots) in various combinations to form the printed characters.

Drill and practice: programs which ask the student a series of questions about a particular topic and evaluate the student's answer. (The better drill and practice programs explain the correct answer to the student.)

Edit: to adjust the format or contents of a document.

Eighty-column card: expansion board which changes the monitor display from 40 columns across the screen to 80 columns.

Electrocardiogram: a graphical representation of the changes in electrical potential occurring during the heartbeat.

Electronic storage: the placement of information on a disk or other medium capable of retaining it for long periods and from which it can be retrieved.

Expansion card: a circuit board which plugs into the computer to give it further capabilities such as additional memory, clock or timer, disk drive controls, printer controls, speech recognition, or built-in programs.

Expansion slot: the openings inside the computer into which the expansion boards are inserted. The Apple IIe computer, for example, has eight expansion slots.

File: a coherent, named piece of information stored on a disk - e.g., a term paper, table of numbers, or a lab report.

Floppy disk: 5 1/4-inch circular piece of plastic which resembles a 45 rpm phonograph record. It is coated with a material that permits the storage of information encoded as magnetic patterns along concentric circular paths.

Gameport: a 16-pin DIP socket through which information can be introduced to the Apple computer.

Gameport extender: a cable which plugs into the gameport. It provides a 16-pin gameport external to the Apple and thus increases the ease of access to the gameport and decreases the need to open the machine.

Graphics tablet: a device which allows drawings to be electronically placed directly on the screen.

Graphics or graphic creations: pictorial representations, such as graphs, charts, and diagrams.

Hands-on: current jargon for actual operation of a piece of hardware.

Hard copy: computer output rendered on paper. (This booklet is an example of hard copy.)

Hard disk: a disk made of a rigid material and coated with a magnetic material. It has large memory capacity and is not removed from the drive.

Hardware: physical computer equipment as contrasted to computer software. The computer, monitor, disk drives, and printer are examples of hardware.

High resolution graphics: representations which have a high density of pixels (light elements) on the display screen (see pixels). The more pixels per inch, the sharper the image.

IC chip: an integrated circuit is a silicon chip containing electronic components such as capacitors, resistors, and transistors in a very small space.

Input device: a device used to put information into the computer. Examples include the disk drive, terminal, card reader, or probe.

Instructional games: programs designed to motivate and instruct students via competition. The games usually require operating within a set of pre-established rules.

Integrate: to make a part of.

Interface box (or card): connector between the computer and some other device.

Interfacing: the act of connecting the computer to some outside device so the two devices can communicate with each other.

Input/output (I/O): a device or process having to do with the transfer of information into or from a computer system.

Joy stick: an input device generally used with arcade-style games to control the animation on the screen. A joy stick contains two game paddles.

K: abbreviation for "kilo". A 64K computer contains about 64 thousand bytes of memory (actually it is 64 x 1024, or 65536).

Laser printer: a computer printer which produces a high quality printed page using the same process as a photocopy machine.

Least squares fit: a method for fitting a curve to a set of data points so that the sum of the squares of the vertical distances from the data points to the curve is a minimum.

LED: light-emitting diode.

Light pen: hand-held light-emitting stylus. When it is held in front of the monitor screen, its position is converted (via an interface card) into an electrical signal that can be interpreted by the software. The pen can be used to add, delete, or move images via direct on-screen communication.

Linear relationship: straight-line relationship -- i.e., one that is described by a first-degree algebraic polynomial function.

Machine language: a programming language composed of a set of unique binary codes that can be executed directly by a computer.

MBL: Microcomputer-Based Laboratory and equipment or software designed for use in science laboratory activities.

Megabyte: one million bytes of information.

Memory extender: a board (or chips) added to a computer to increase the size of its random access memory (RAM).

Menu: a screen-displayed list of computer task options from which selections can be made.

Menu driven: describes a program in which a main menu directs the user to other more detailed menus listing further tasks or options.

MECC: Minnesota Educational Computer Consortium.

Modem: MOdulator-DEModulator -- a device that in the sending mode converts digital data output from a computer into a signal that can be transmitted over standard communication lines. In the receiving mode, it converts the signal back to digital data that the computer can interpret.

Monitor: a receiver which contains a cathode ray tube or light emitting diodes upon which the computer output can be seen. A television screen can be used as a monitor.

Monochromatic: one color.

Mouse: a hand-held device whose movement over a flat surface is reflected in the movement of the cursor on the monitor screen. It is used to select locations on the screen.

Open architecture: provision of space in a computer for add-on boards along with public sharing of information regarding the arrangement of components in the computer, thus allowing other manufacturers to produce compatible boards and peripherals for the computer.

Paddles, Game: variable resistors in hand-held devices that permit control of the animation in arcade-style games.

Paddle number: a number between 0 and 255 which is related to the resistance of the game paddle.

Peripheral device: any piece of equipment used to input or output information to/from the CPU -- e.g., disk drive, terminal, monitor, cassette recorder, or printer.

Photogates: photodetectors which, with the breaking of a beam of light, signal on/off to the computer.

Photoresistor: material whose electrical resistance changes with the amount of light which falls on it.

Photosensitive: sensitive to light.

Phototransistor: integrated chip designed to vary the current in response to changes in light intensity.

Pixel: PICtureS ELement. One pixel is the smallest unit of information that can be shown on the monitor screen.

Power strip: an electrical outlet extender containing several outlets; usually plugged into a wall outlet.

Printer: (See daisy, dot matrix, laser, thermal.)

Printer card: board which allows communication between the printer and computer and is often in slot 1.

Printout: Computer output printed on paper.

Public domain software: computer programs which are available to users without payment of a royalty to the author.

Push buttons: on/off switches on the game paddle.

RF converter: Radio Frequency converter allows the use of a television monitor instead of a computer monitor.

RGB: red-green-blue.

Random access memory (RAM): a type of memory in which any location can be accessed directly and its contents read or changed. RAM is not permanent and disappears when the machine is turned off (volatile memory).

Real science: laboratory questions and investigations which foster inquiry.

Real time: program output (such as a graph) is produced and displayed as the data are collected.

Screen dump: reproduction of the contents of the monitor screen on paper via the printer.

Sensor: a device that responds to a physical stimulus and transmits a resulting signal.

Signal splitter: a "Y" - shaped cable that "splits" the computer output signal for simultaneous display on two monitors.

Simulations: computer programs which imitate experiments or natural systems. Conditions of the experiment may be changed and effects noted in real time. Simulations often involve graphics.

Site license: permission to make copies of software for your school according to conditions specified in the contract.

Software: programs, languages, or routines that control the operations of a computer.

Spreadsheet: a program which permits the organization of numerical data into rows and columns and permits calculations with the data via user-specified formulas.

Surge protector: a device that prevents a large voltage from suddenly entering electrical circuitry.

Switch: a device in a circuit that allows or breaks the flow of electricity in that circuit.

Teacher utility: computer program which makes clerical functions such as record-keeping, assigning grades, or inventory control easier.

Thermal printer: a printer in which the image on the printed page is formed by a heat process.

Transducer: device which converts energy from one form to another -- for example, the conversion of heat into electricity.

Tutorial: a software program which prompts or leads the student through a particular set of skills or concepts. Good tutorials provide for a change of pace, presentation of explanations, and modification of the number of cycles based on the responses of the user (learner).

Ultrasound: high frequency sound which is beyond the hearing range of human beings (above 20,000 Hertz).

Utility: a program which performs tasks required by many of the programs using the system or does a job which is commonly required -- such as copying the contents of one disk onto another.

Voltage: electrical potential

"What if" questions: questions seeking to find the consequence of changing initial conditions or hypotheses.

APPENDIX A

EXAMPLES OF COMMERCIAL MBL PRODUCTS

INTERFACING WITH TEMPERATURE PROBES

The following is an example of an MBL temperature plotting system with which we have had success.

Temperature Plotter (Vernier)

Temperature Plotter consists of an interface box, one to four temperature probes, documentation, and a software disk. With this equipment you can read, store, and graph the data from up to four probes (thermisters) for time intervals ranging from one second to 24 hours. Further options permit display of the temperatures in large print on a monitor (for classroom viewing) and viewing or printing data tables and graphs using Fahrenheit, Celsius, or Kelvin scales. The limited "live" data graphing option is a minor shortcoming. The documentation is outstanding in that it provides background information on interfacing theory and the operating principles of the equipment. Temperature Plotter may be used for both middle and high school investigations involving temperature monitoring.

Other systems:

Temperature Lab (Creative Technology)
Heat and Temperature (Human Relations Media)
Temperature Grapher (HRM)
Temperature Experiments (Hartley)
Science Tool Kit Master Module (Broderbund)

INTERFACING WITH LIGHT PROBES

MBL systems involving light probes fall into two categories - determining the frequency of events and measuring light intensity.

MBL Systems for Timing or Frequencies

Precision Timer (Vernier)

Vernier's Precision Timer Kit contains the components necessary for constructing an interface box and comes with three photogates, documentation, and a software disk. We assembled these interface boxes and housed the photogates in 3/4-inch plastic PVC pipes rather than the metal supports

provided in the kit. The result was an exceptionally durable and versatile piece of equipment. The documentation is outstanding with regard to its presentation of suggested use, theory of operation, and guidelines for construction of the equipment. If you follow directions carefully and assemble the electronic box and photogates (used for making small time measurements and determining the frequency of recurring events), the quality of the equipment and the cost savings will be worth the effort.

Precision Timer (Pasco)

The Pasco kit contains photogates, an interface box that will support two photogates, and a software disk. The documentation is excellent. All components come assembled. This system, like Vernier's Precision Timer Kit, is used to measure short time intervals. A typical example of its use in physics would be to find the period and speed of a pendulum.

MBL Systems for Light Intensity

Science Toolkit Master Module (Broderbund)

Science Toolkit Master Module contains an interface box, temperature and light sensors, and a software disk. The versatility of the software permits making measurements of light intensities (in foot candles) and presenting them in either meter or strip chart modes. A timing mode (stop clock) also is available. The attractive graphics presentations and the variety of measurements that the program enables make this a highly useful package. The teacher/student activity manual also is very helpful.

Experiments In Science (Human Relations Media)

Experiments In Science allows interfacing of both temperature and light sensors. One component of this kit permits using a photoresistor to sense, and software to compute, the energy of incoming light in watts per square meter and to give the cumulative energy input in joules. (When the source of the incoming light is the sun, such an activity is called an in sol ation experiment.) Before the advent of MBL, such simple direct timed measurements were beyond the reach of high schools.

Cardiovascular Fitness Lab (Human Relations Media)

The Cardiovascular Fitness Lab consists of an interface card that is installed in one of the auxiliary slots in the Apple computer, a light source in the form of a light emitting diode (LED) paired with a light detector (phototransistor) which can be clipped to an ear lobe or finger, a software disk, and documentation. Since changing blood volume affects the light intensity received by the phototransistor, the pulse rate can be determined for an interval as short as one second. Program options permit plotting a real time graph or a histogram. Either format can be viewed "live" on the screen.

An exercise training mode also is available. We have used this MBL device extensively and have found that it has many applications -- especially in biology, where it is an excellent tool for student reseach projects.

INTERFACING WITH SOUND PROBES

The following three examples of MBL systems employ the use of sound probes.

Frequency Meter (Vernier)

Frequency Meter consists of a set of parts to build a microphone, documentation, and a software disk. A cassette recorder with an output jack may be substituted for the microphone to eliminate the need for construction of the microphone. A program option permits use of the equipment as a general purpose audio-range frequency meter. The detected frequencies can be displayed on the monitor screen, edited, and stored. Another option permits using the Frequency Meter with a photogate to determine the angular speed of a rotating object. The documentation includes background information and suggested activities. This inexpensive package has many classroom possibilities.

SOUND, A Microcomputer Based Lab (Human Relations Media)

This package consists of a microphone, interface box with connecting cables, software disks, and a (student) resource manual. With the equipment and program, sound can be detected and shown in wave form on the screen in three display modes: Show Waves Continuous, Show One Wave, Show and Magnify. The student resource manual offers background information as well as activities.

Motion, A Microcomputer Based Laboratory (Human Relations Media)

The package consists of an ultrasonic range finder, software disks, and documentation. Data gathering begins with an electrostatic ultrasonic transducer which sends out pulses of ultrasound that reflect from the object of interest and are reflected back to the ranger. (The system is the same as the one used by bats to catch food and to avoid objects.) Upon receiving the reflected pulses the software program calculates the position of the object relative to the ranger. Positions of the object are plotted in real time on the monitor screen (distance vs time graph). Using the distance-time data the program also can generate velocity vs time and acceleration vs time graphs.

This interfacing device has many excellent applications in the study of kinematics. Its versatility can be demonstrated via the position, velocity, and acceleration vs time graphs describing the motion of a pendulum through multiple oscillations. Teachers will appreciate the quality of this method compared to the "ticker-tape" method which required the attachment of a tape to the pendulum and, at that, produced data from just one-half cycle. The documentation is excellent, containing both background information and specific student laboratory activities. Micromint Inc. offers the ranger as an assembly kit and several companies retail the software.

APPENDIX B

EXAMPLES OF MBL ACTIVITIES

EARTH SCIENCE

EFFECT OF ANGLE OF INSOLATION ON SURFACE TEMPERATURE CHANGE

INTRODUCTION

The sun heats the surface of the earth during the day with radiant energy (INcoming SOLar radiATION or insolation). The angle of insolation is the angle, measured from the horizontal, at which the sun's rays strike the surface of the earth. The angle varies with latitude, date, and time of day. More generally, if we have a solar collector that is not necessarily horizontal, the angle of insolation is the angle at which the sun's rays strike the plane of the collector.

PURPOSE

The purpose of this investigation is to test the effect of the angle of insolation on the temperature of the surface. You will do this by shining a bright light on four (4) black paper envelopes set at various angles to the "sun's" rays.

HYPOTHESIS

Based on your own intuition, predict whether the greatest increase in the surface temperature will occur when the angle of the light's rays is:

a. 90 degrees to the surface
b. 60 degrees to the surface
c. 30 degrees to the surface
d. 0 degrees to the surface

MATERIALS

Apple Computer system with printer, Vernier temperature plotter, Vernier system with four temperature probes calibrated for 20-40 degrees C, meter stick, ring stand, floodlight with reflector, masking tape, protractor, four black construction paper envelopes (4 cm x 4 cm)

PROCEDURE

Getting Started

1. Plug the temperature probes into their proper positions on the interfacing box. Plug the interface box into the Apple game port.(Do not hesitate to ask your instructor for assistance.)

2. Insert the Temperature Plotter disk into the disk drive and turn on the computer.Be sure the CAPS LOCK key is depressed.

3. Press Y then RETURN to "select probes" from the Main Menu. To select all four probes (A,B,C,& D) as the active temperature sensors, press ABCD then RETURN.

Setting Up the Experiment

4. Slip the four black paper envelopes over the ends of the temperature probes so that the end of each probe is in the center of the paper square.

5. Tape the four probes in order to the edge of the table so that the four paper envelopes extend beyond the lip of the table with their flat edges just touching.

6. Place the lamp 30 cm above the four envelopes (measure with the meter stick) so that the lamp will illuminate all the envelopes equally when it is turned on. The centering of the lamp is extremely important.

7. After the probes have been taped to the edge of the table, rotate the paper envelopes (using a protractor as a guide) so that the angles at which the light rays strike their surfaces are:

for probe A - 90 degrees
for probe B - 60 degrees
for probe C - 30 degrees
for probe D - 0 degrees

Running the Experiment

8. Return to the Main Menu and press M to "monitor temperatures".

9. When the computer asks you if you want to save your data, press Y for YES. Choose 20 seconds as the time between recorded temperature readings. Enter 120 as the total number of temperature readings to be recorded (4 probes X 3 readings per probe per minute X 10 minutes).

10. Turn on the heat light. Press RETURN to begin taking temperature readings.

11. When all temperature readings have been taken, turn off the flood light and press RETURN to go to the Main Menu.

Printing Your Data

12. Be sure that your computer is attached to a printer, that the printer is supplied with paper, that the printer power light is on and the "select" light is on. Press T and RETURN to print a copy of the data table. When the program asks for the slot to which your printer is attached, press 1. When the printing has been completed, press RETURN for the Main Menu.

13. Repeat the previous step as many times as needed to provide each member of your group with a copy of the data table.

14. Press P to choose PLOT THE GRAPH from the Main Menu. Press B to choose automatic scaling of the temperature axis with respect to a variable (nonzero) origin. From the next graphing menu, press A to choose automatic scaling with relative time. Then from the NEXT graphing menu, press LG and RETURN to choose a line graph with a grid. After a brief interval, the graph will appear on the screen.

    The lines are identified as follows:

Probe	Symbol	Angle of insolation
A	[]	90 degrees
B	△	60 degrees
C	+	30 degrees
D	X	0 degrees

    Press RETURN when you have finished looking at the graph.

16. Press 0 (not zero) to choose "Print graph on printer" from the graphing menu that appears after the graph has been displayed. Press either G or I to indicate that your printer has a Grappler interface card or that you have an Imagewriter printer. Press 1 to indicate that your printer is connected to slot 1. Then, by hand, label each temperature graph on your hard copy with its angle of insolation.

17. Repeat the previous step until each member of your team has a copy of the graph.

18. Turn off the computer and put all the apparatus away as directed by your instructor. Be sure to keep your temperature measurement system together as a set and that each component of the set is labeled with the set number.

CONCLUSION ABOUT YOUR HYPOTHESIS

Calculate the change in temperature of each envelope at each angle of insolation by subtracting its minimum temperature from its maximum temperature in your data table. At which angle did the envelope heat up the most? least?

Write a conclusion about your original hypothesis. Be sure to support your conclusion with your data.

FOR FURTHER THOUGHT

1. What assumption about our experimental setup is affected by the position of the lamp over the envelope?

2. Do you think that all the envelopes would eventually reach the same temperature if the floodlights were left on long enough? Explain your answer using your data.

3. Which envelope would represent the angle of insolation at the Earth's poles at noon on the dates of the equinoxes? at the equator?

4. Using the data obtained in this lab, explain why the average temperature at the Earth's poles is less than the average temperature at the equator.

5. If you were setting up solar energy panels, at what angle would you set them with respect to the insolation? Make a diagram to aid your explanation.

6. The position of fixed solar energy panels in Connecticut is generally more vertical than the position of fixed solar energy panels in Florida. Can you suggest a reason for this difference? Make a diagram to aid your explanation.

7. Examine the graph of your data. Did the envelope with the greatest increase in temperature have the fastest increase in temperature? What do you think is the relationship between the <u>rate</u> of temperature increase and the <u>size</u> of the increase?

8. What would happen if white envelopes were placed over the temperature probes?

BIOLOGY

INVESTIGATING THE EFFECT OF BREATHING STYLE ON HEART RATE

INTRODUCTION

We take air into our lungs by increasing the size of the thoracic cavity to reduce the pressure inside our chests. The thoracic cavity is enlarged either by expanding the rib cage or by pulling down the floor of the cavity with the diaphram. One way to differentiate between breathing with your diaphram and breathing with your rib cage is to lie on the floor, placing one hand so that the little finger is on your navel and the thumb on your breast bone: only the little finger should move up and down during abdominal (diaphram) breathing; only the thumb should move up and down during chest (rib cage) breathing.

PURPOSE

In this experiment you will determine how your heartbeat pattern is affected by the style of breathing (chest breathing versus abdominal breathing).

HYPOTHESIS

(Choose a hypothesis based on your present knowledge. If you do not like any of the suggested hypotheses, create your own.)

I predict that breathing with the chest will

a. result in the same heart rate pattern as breathing with the diaphram.
b. affect the heart rate pattern more than breathing with the diaphram.
c. affect the heart rate pattern less than breathing with the diaphram.

MATERIALS

Apple computer with printer, Cardiovascular Fitness Lab, blanket

PROCEDURE

Record the heart rate of several different people using the plotting mode with a plotting interval of 1 second and an experiment length of two minutes. Make three recordings for each person -- normal breathing, diaphram breathing, and chest breathing. Use the event marker to note when the person inhales (breathes in). Make a printed copy of each heart rate recording for each member of your group before beginning the next heart rate recording.

CONCLUSION ABOUT YOUR HYPOTHESIS

Write a conclusion about your hypothesis. Explain how the data gathered during the experiment supports your conclusion. Be sure to discuss any sources of error or lack of controlled conditions that may have affected your results.

FOR FURTHER THOUGHT

1. Propose an explanation for the effect of the two types of breathing on the heart rate pattern.

2. Propose two methods that we could use to eliminate the effect of breathing style on heart rate measurements during other heart rate investigations.

CHEMISTRY

THE COOLING CURVE OF A PURE SUBSTANCE

INTRODUCTION

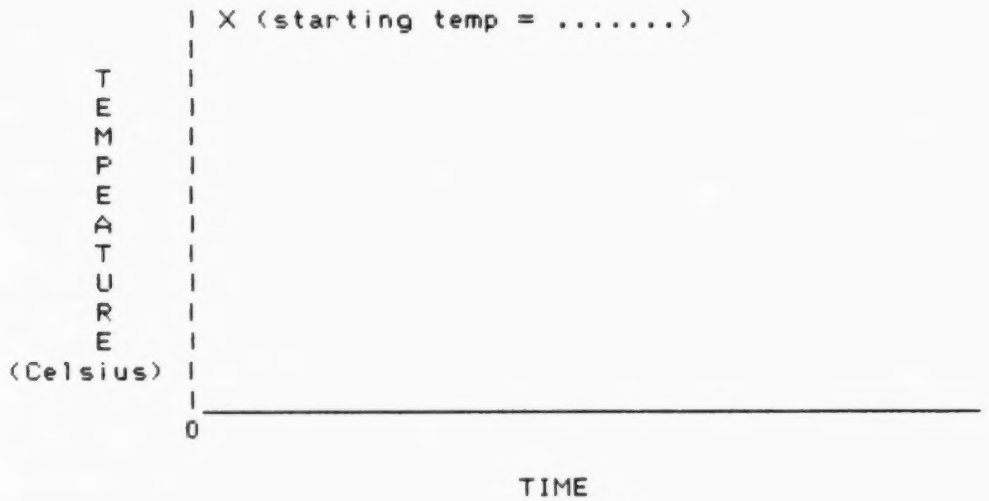
The study of a material as it cools, solidifies, and cools further is a topic studied in many first-year high school chemistry courses. Students often are asked to experimentally determine the cooling curves for water, para-dichlorobenzene, acetamide, or napthalene: what is the shape of the cooling curve for the liquid (temperature versus time) and how does the energy change during the fusion process?

PURPOSE

The purpose of this laboratory activity is to determine the cooling curve for acetamide and the temperature of the cooling agent through the same time period.

HYPOTHESIS

Using the graph format provided below, sketch your prediction of the cooling curve for acetamide.



MATERIALS

Apple computer, Vernier temperature plotting MBL system with two probes, acetamide, one large and one small test tube, Bunsen burner and hot water bath, ice bath, and test tube holders. The small test tube containing the acetamide must be able to nest within the larger test tube with allowance for a probe and air space between them.

PROCEDURE

Become operational with TEMPERATURE PLOTTER -- i.e., be able to collect data and save it in memory using a sampling delay time of 12 seconds. WEAR SAFETY GOGGLES . Place the acetamide test tube into boiling water. Put thermometer probe A into the acetamide as soon as it (the acetimide, not the thermometer!) becomes molten. Put probe B into the large test tube (which will later surround the acetamide test tube). Cool the large test tube in the ice bath. When the large test tube (with probe B) is cool, remove it from the ice bath. At this time, activate the computer to begin data collection. Put the acetamide test tube (containing probe A) into the large cool test tube (containing probe B).

While the apparatus collects the data, make observations of the acetamide and record them in your laboratory notebook. Data should be collected until the temperatures of probes A and B are within three degrees of each other.

Using MENU options save your data and print out graphs of the temperatures of probes A and B.

A. Label the part of the graph which represents the cooling of the liquid acetamide.
B. Label the point where solidification starts.
C. Label the part of the graph that shows when acetamide is solidifying.
D. Label the part of the graph that shows when acetamide is solid and cooling.

CONCLUSION ABOUT YOUR HYPOTHESIS

Compare the experimental graph of cooling acetamide to your hypothesis. Write a conclusion about how your hypothesized graph compares to the actual graph.

QUESTIONS

1. What happens to the temperature of the acetamide as it is cooled and solidifies?

2. What happens to the temperature of the cooling agent during the same time?

3. Why is it that although acetamide continues to cool during the solidification process its temperature doesn't decrease?

4. Is the acetamide losing kinetic or potential energy during the phase change?

5. How do you know acetamide is losing heat energy during the solidification process if its temperature is not decreasing?

FURTHER ACTIVITIES

Reverse the process by recording the temperatures while solid acetamide is warmed, melted, and further heated. Is the process reversible?

PHYSICS

VELOCITY OF AN OSCILLATING OBJECT USING THE SONIC RANGER

INTRODUCTION

In the physical world a myriad of objects oscillate in Simple Harmonic Motion (SHM). In damped SHM motion, the size of successive oscillations decreases.In this activity we shall investigate the relationship between the position and the velocity of a mass hanging from a spring that is undergoing damped SHM as it oscillates vertically: how does the velocity change as the position changes?

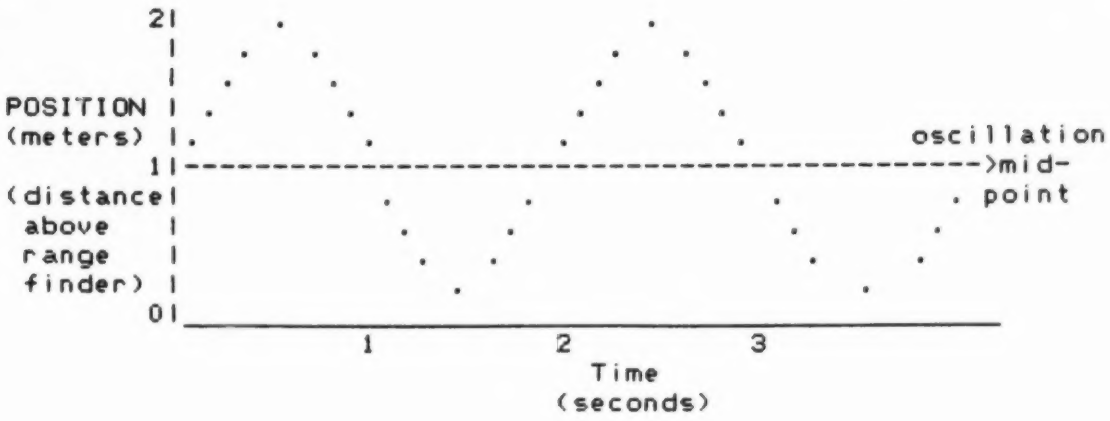
The position of the mass can be determined using an ultrasonic range finder, computer, and MBL software. The sonic ranger sends out pulses of ultrasound that reflect from the mass and return to the ranger (similar to the way in which bats and whales hunt for food). The speed of the pulses is known and the travel time can be determined. The computer software then can calculate and plot the positions of the mass during the oscillations.

PURPOSE

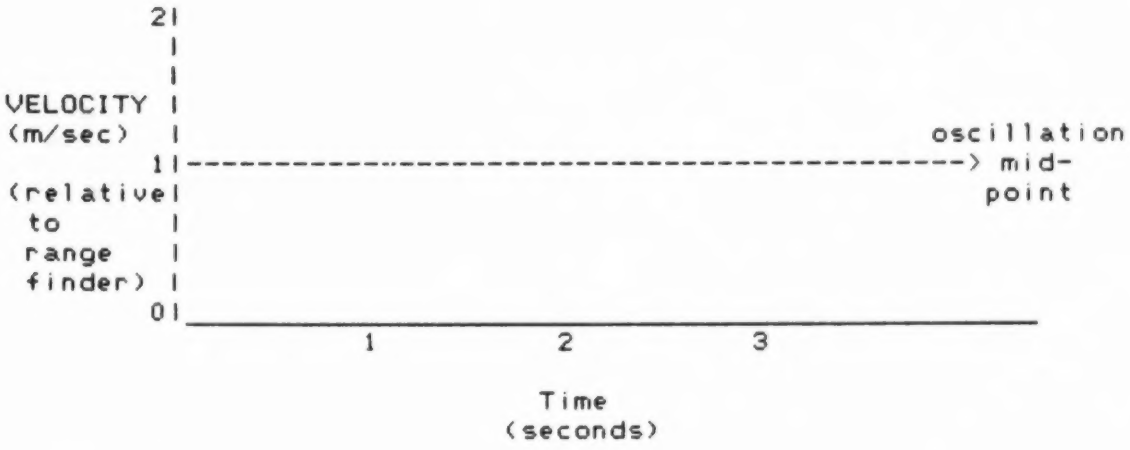
The purpose of this laboratory activity is to investigate the relationship between the position and velocity of a mass attached to a spring as it undergoes damped vertical SHM.

HYPOTHESIS

The following graph shows vertical position versus time for the oscillating mass.



Now, use the graph axes below and construct the velocity vs time graph that would result from the position vs time graph above. (Remember that velocity is the change in position per time interval.) Use this graph to write your hypothesis.



MATERIALS

Apple computer, sonic ranger, software disk, one-kilogram mass, ring stand, universal clamp, "C" clamp, 60 cm spring (CENCO, catalog #75490 or equivalent)

PROCEDURE

1. Use the "C" Clamp to clamp the ring stand to the edge of the bench. Use the universal clamp to attach one end of the spring to the ring stand so that it hangs over the edge of the bench. Attach a one-kilogram mass to the other end of the spring so that the mass can oscillate vertically.

2. With the computer off, plug the sonic ranger into the 16-pin DIP plug on the Apple computer. Place the ranger on the floor directly below the mass.

3. Turn on the computer. Become operational with the sonic ranger so you can produce distance vs time graphs.

4. Test the oscillation so that the mass moves through a distance of about 50 cm and does not come within 30 cm of the sonic ranger.

5. Experiment with raising and dropping the mass and producing the distance vs time graphs and work out any "bugs" in the arrangement of your apparatus. If necessary, rescale the distance and time axes.

6. Produce a distance vs time graph for the oscillating mass.

7. Now have the computer produce a velocity vs time graph using the position and time data.

CONCLUSION ABOUT YOUR HYPOTHESIS

Compare the original velocity vs time graph in your hypothesis to the one produced by the computer. Write a conclusion for your hypothesis.

FOR FURTHER THOUGHT

1. What would the acceleration graph look like for the oscillating mass? Make a prediction and then test your prediction using the computer.

2. How would the velocity for a given displacement change with an increase or decrease in mass? Make a prediction and then test it.

3. How does the position vs time graph show damping (reduction of amplitude over time) of motion? What is the cause of this damping?

4. How would the position, velocity, and acceleration vs time graphs for non-damped SHM compare to those where damping is evident?

5. What two major opposing forces are at work on this oscillating object? How does each force vary with the vertical position of the mass?

6. At what vertical position did the mass have the greatest velocity? Explain this in terms of the forces acting on the mass.

SUGGESTIONS FOR OTHER ACTIVITIES USING THE SONIC RANGER

1. The movement of students can be recorded by the sonic ranger. The teacher may specify different shapes for displacement, velocity, and acceleration graphs and have students create movements that will give the desired shape to the graph. Such an activity can give students a good understanding of the types of motion described by various displacement, velocity, and acceleration graphs.

2. The motion of the common pendulum is easily recorded by the sonic ranger. Studies could be done comparing position, velocity, and acceleration of the pendulum.

3. Via experimentation using the sonic ranger, find an object that exhibits terminal velocity in free fall.

APPENDIX C
SOURCES OF MBL PRODUCTS
(REVISED July 1987)

This product list has been divided into four parts:

1. microcomputer based science laboratory materials that are complete packages (computer interface + sensors + software)

2. printer interfaces that allow Apple users to print graphics (a paper copy of graphs that appear on the video screen)

3. sources of components for the construction of microcomputer- based science laboratory equipment

4. game port extenders and adapters for Apple users

The original producer of a product is listed whenever possible. You may buy many of the products listed here from distributors at a discount. Few of these products have been previewed by the authors. If you have any additions or corrections to this list please write to Robert Pease, Conard High School, 110 Berkshire Road, West Hartford, CT 06107; (203) 521-1350. Prices and product availability may well have changed since publication of this list. PIMMS is not responsible for ommissions or errors.

1. MBL EQUIPMENT

American Data Cable
P. O. Box 2212
Placerville, California 95667
(916) 622-3465

Item	Price	Computer
One channel temperature system	$149.50	Apple & IBM
One channel humidity system	$169.50	Apple & IBM
One channel voltage system	$149.50	Apple & IBM
One channel resistance system	$149.50	Apple & IBM
Multichannel expander	$129.50	Apple & IBM
Strip chart recorder	$89.00	Apple & IBM
Graphics Printing Option (16 Bit resolution, eight channel systems also available)	$24.50	Apple & IBM

Broderbund Software Direct
P.O. Box 12947
San Rafael, California 94913-2947
(415) 479 1185

Item	Price	Computer
Science Tool Kit - Master Module (temperature, photocell, exp't manual)	$69.95	Apple
Science Tool Kit - Teachers Guide	$20.00	
Module 1 - Speed and Motion (requires master module)	$39.95	Apple
Module 2 - Earthquake Lab (requres master module)	$39.95	Apple

Cambridge Development Laboratory
1696 Massachusetts Avenue
Cambridge, Massachusetts 02138
(800) 637 0047
Hardware-software combination

Item	Price	Computer
Experiment Interface (w/ cable) ADC	$575.00	TRS 80
Experiment Interface (w/ cable) ADC	$585.00	Atari
Experiment Interface (w/ cable and RS 232C Serial Port)	$755.00	Apple
Temperature module	$195.00	
Light module	$150.00	
pH module	$150.00	
Angular momentum module	$195.00	
Voltage module	$150.00	

Central Scientific Company
11222 Melrose
Franklin Park, Illinois 60131
(800) 262 3626

Item	Price	Computer
Measurement Module (temp., voltage, current, magnetic field)	$520.00	Apple
PSSC Photoelectric Interface	$129.00	Apple
PSSC Software disks	$129.00	Apple
PSSC Kinematics Software	$65.00	Apple

Computer Assisted Science Labs
6818 86th Street East
Puyallup, Washington 98371
(206) 845 7738

Item	Price	Computer
Chemistry lab software system (includes 24 labs, manual, 4 disks, RS 232 interface and cable, needs either of the balances below)	$475.00	Apple
General science lab software system (includes 16 labs, manual, 3 disks, RS 232 interface and cable, needs either of the balances below)	$400.00	Apple
OHAUS Galaxy G400 Balance	$1095.00	
OHAUS Port-O-Gram C501 Balance	$470.00	

Creative Technology Inc.
P.O. Box 1009
Carlisle, Pennsylvania 17013
(717) 245 2988

Item	Price	Computer
Science Discovery Temperature Lab	$100.00	Apple and C64
Science Discovery Light Lab (needs Temperature Lab)	$50.00	Apple and C64
Both of above	$135.00	
Science Discovery Temperature Lab	$85.00	Atari
Science Discovery Light Lab (needs Temperature Lab)	$50.00	Atari
Both of above (all above come with experiment manuals)	$135.00	

Cross Educational Software
P.O. Box 1536
Ruston, Louisiana 71270
(318) 255 8921

Item	Price	Computer
Physics Lab - Sound	$60.00	Apple
Physics Lab - Heat	$60.00	Apple
Physics Lab - Light	$60.00	Apple

Daedalon Corporation
Box 2028
Salem, Massachusetts 01970
(617) 744 5310

Item		Price	Computer
Interface card		$45.00	C64 & VIC 20
Computer photogate		$50.00	
Picket fence target		$12.50	
Electronic Atwood's machine		$325.00	
Reflectance photogate		$24.50	
Geiger computer interface (requires high voltage source)		$95.00	C64 or Apple
Geiger tube		$125.00	Apple
Geiger tube and cable		$133.50	C64
Timer 100	Cassette	$19.50	C64 or VIC 20
	Diskette	$24.50	C64 or VIC 20
	Cartridge	$45.00	C64
Plot and fit and printer	Cassette	$19.50	C64 or VIC 20
	Diskette	$24.50	C64 or VIC 20
Freefall	Diskette	$24.50	C64 or VIC 20
Atwood's machine data processing	Diskette	$24.50	C64
Geiger counter program	Diskette	$24.50	C64 or Apple

D.C. HEATH software
Collamore Educational Publishing
125 Spring Street
Lexington, Massachusetts 02173
(800) 428 8071

Item	Price	Computer
Exploring heat through lessons & labs	$200.00	Apple
Exploring matter through lessons & labs	$200.00	Apple

Digipac
907 River Street East
Prince Albert, SK
Canada, S6V 0B3
(306) 764 1707

Item	Price	Computer
Time machine (above includes 2 infrared photogates)	$49.95	Apple
The Temperature Gauge	$60.00	Apple
Graphical Analysis	$29.95	Apple

Dreyfus Institute
Woodrow Wilson National Fellowship Foundation
Box 642
Princeton, New Jersey 08540

Item	Price	Computer
Instructions and program listing for the construction of a photometer, thermoprobe, and a gas chromatograph. Program must be typed in. Units are to be built from inexpensive, locally obtained parts.	free	Apple

E and L Instruments
70 Fulton Terrace
New Haven, Connecticut 06512
(800) 225 0125 or 624 3103

Item	Price	Computer
Chempac (includes computer system w/ printer, interface, 2 thermisters, 2 thermometers, colorimeter, pressure sensor, pH sensor, and EMF sensor)	$2450.00	C64

Educational Materials and Equipment
Box 2805
Old Mill Plain Road
Danbury, Connecticut 06811
(800) 345 2050
(203) 798 2050

Item	Price	Computer
Temperature Interface	$98.00	Apple

Edutech
303 Lamustive Street
Jamaca Plain, Massachusetts 02130
(617) 524 1774

Item	Price	Computer
Comptrol Lab Temperature (2 disks, lab manual, 2 thermistor probes, instrument manual)	$195.00	Apple
Comptrol lab Mechanics (2 pendulum disks, 2 acceleration and momentun disks, 1 photogate, manuals, interface, banded ruler)	$285.00	Apple
Fourier Analysis I (needs Mountain computer ADC)	$55.00	Apple
Fourier Analysis II (needs Mountain computer ADC)	$55.00	Apple
Physical Science Experiments	$150.00	Apple

Frey Scientific
905 Hickory Lane
Mansfield, Ohio 44905
(800) 225 3739

Item	Price	Computer
Simple Interface Kit	$129.00	Apple & C64
Temperature Lab (for above)	$85.00	Apple & C64
Light Lab (for above)	$69.00	Apple & C64
Sound Lab (for above)	$69.00	Apple & C64
Battery Lab (for above)	$49.00	Apple & C64

Hartley Courseware, Inc.
133 Bridge Street
Box 419
Diamondale, Michigan 48821
(800) 247 1380

Item	Price	Computer
Temperature Experiments	$69.95	Apple

Holt, Rinehart and Winston
CBS Inc., 383 Madison Avenue
New York, New York 10017

Item	Price	Computer
Bank Street Laboratory (Packaged as part of the "Voyage of the Mimi")	$370.50	Apple

Human Relations Media (HRM)
175 Tompkins Avenue
Pleasantville, New York 10570
(800) 431 2050

Item	Price	Computer
Biofeedback Microlab	$350.00	Apple,C64
Cardiovascular Fitness Lab	$175.00	Apple,C64,IBM
Experiments in Science	$259.00	Apple
Experiments in Chemistry	$349.00	Apple
Experiments in Colorimetry	$175.00	Apple
Experiments in Human Physiology	$259.00	Apple
Experiments in Artificial Intelligence: Robotics	$259.00	Apple,C64
Temperature Grapher	$79.00	Apple
Motion	$220.00	Apple
Heat and Temperature	$289.00	Apple
Sound	$199.00	Apple
Body Electric	$350.00	Apple
Fall Guy	$175.00	Apple
Trackstar (Apple simulator for IBM PC or Tandy 1000)	$395.00	IBM

IC-REF
2310 Dorothy Avenue, Suite 5
Lousiville, Kentucky 40205

Item	Price	Computer
Apple II interface box	$100.00	Apple
Apple Eyes	$75.00	Apple
(photogate timing experiments)		

Intellitool Inc.
429 South West Street
Wheaton, Illinois 60187
(312) 653 7657

Item	Price	Computer
Physiogrip	$400.00	Apple
(muscle physiology principles)		
Cardiocomp	$950.00	Apple
(electrocardiograms)		

J & L Enterprises
Box 6195
Alhambra, Califronia 91802
(818) 570 9767

Item	Price	Computer
Physics Laboratory Experiments with Computer Interfacing (lab manual)	$7.99	Apple

Kemtec
Silver Springs, Maryland
(distributed by Wards, Sargent Welch, Fisher, Frey, Science Kit, Kon's)

Item	Price	Computer
Kemtec Colorimeter	$100.00	Apple
Enzyme Kinetics kit (for above)	$30.00	
(calculates Vmax and Km)		

Laserpoint
202 West Muncie Avenue
Fresno, California 93711
(209) 435 5273

Item	Price	Computer
Laboratory Interfacing Disk	$79.95	Apple
Laboratory Interfacing Kit	$149.95	Apple

Merlan Direct
247 Armstrong Avenue
Georgetown, Ontario
Canada L7G 4X6
(416) 877 0171
(800) 387 2474

Item	Price	Computer
Computimer program	$84.00	32K Pet/C64
Computimer hardware	$75.00	32K Pet/C64
Champ interface system (2 ADC inputs & 2 logic inputs)	$489.00	Apple, C64
Champ software - sensor pack	$149.00	Apple, C64
Champ software - scope chart	$149.00	Apple, C64
Champ software - sigpro	$149.00	Apple, C64
Harris Interface (4 ADC inputs & 2 analog outputs w/ software)	$489.00	Apple
(all sensors below are for both Champ and Harris interfaces)		
Position transducer	$112.00	
Light sensor	$75.00	
Temperature sensor	$111.00	
Oxygen sensor	$81.00	
Oxygen electrode	$98.00	
Oxygen electrode membrane	$20.00	
Temperature compensating thermistor	$20.00	
Humidity sensor	$154.00	
pH Sensor	$74.00	
Pressure sensor	$211.00	
Manometer	$78.00	
Manometer tube	$77.00	
Electronic barometer	$205.00	
Strain gauge	$183.00	
Magnetic sensor	$121.00	
Voltmeter sensor	$95.00	
Ammeter sensor	$99.00	
Ratemeter sensor	$130.00	
(also see Tel-Atomic for Harris sensors)		

Nagawtis Software Research
10243 Pineland Drive
Houston, Texas 77024
(713) 465 1079

Item	Price	Computer
Data Grabber Double (software for ultrasonic ranger)	$70.00	Apple
Data Grabber Elite (software for ultrasonic ranger)	$65.00	Apple
Range-finding Transducer modules	$95.00	Apple

Narco Bio-systems (Sci-lab computer based science software)
7651 Airport Blvd
Houston, Texas 77061
(713) 644 7521

Item	Price	Computer
Sci-lab prog. signal conditioner	$650.00	Apple
A to D PC board assembly	$295.00	Apple
Biology transducer pack (ECG, respiration, dynamometer, and bubble detector)	$485.00	Apple
Chemistry transducer pack (pH, temperature)	$160.00	Apple
Physics transducer pack (force, gravity tube, motion)	$435.00	Apple
Following is software for above		
Rate of photosynthesis	$85.00	Apple
Rate of yeast fermentation	$85.00	Apple
Electrical activity of the heart	$85.00	Apple
Skeletal muscle activity	$85.00	Apple
Evaluation of physical conditioning	$85.00	Apple
Mechanics of respiration I	$85.00	Apple
Measuring temperature and heat	$85.00	Apple
Energy and phase changes	$85.00	Apple
Heat of fusion	$85.00	Apple
Hydronium ion conc. and pH	$85.00	Apple
Indicator colors & pH: hydrolysis	$85.00	Apple
Titration of a strong acid	$85.00	Apple
Metric system	$85.00	Apple
Average and instantaneous velocity	$85.00	Apple
Acceleration	$85.00	Apple
Acceleration due to gravity	$85.00	Apple
Resolution of forces	$85.00	Apple
Force of friction	$85.00	Apple

Pasco
1876 Sabre Street
Hayward, California
(800) 772 8700

Item	Price	Computer
Model 9204 Accessory photogate	$75.00	Apple
Model 9260 Photo-Reflective Sensor	$295.00	Apple
Model 6575 Apple gameport interface	$98.00	Apple
Model 9259 Laser Switch	$70.00	Apple
Model 9346 Sonic Ranger System	$289.00	Apple
Model 9340 Smart Pulley System	$195.00	Apple
Model 9343 Adapter Cable	$13.00	Apple
Model 7410 Driven Harmonic Motion Analyzer Software	$50.00	Apple

Project Serapnim
Department of Chemistry
Eastern Michigan University
Ypsilanti, Michigan 48197

Item	Price	Computer
Heats of reaction disk	$5.00	Apple,C64
Photochrome kinetics disk	$5.00	Apple,C64
General Laboratory Interfacing disk	$5.00	Apple,C64,IBM
Data Collection & Retrevial system disk	$5.00	Apple,
Record and recall spectra	$5.00	Apple
Directions to make Apple Adapter Box	$4.00	
Instructions to build Blocktronic I	$4.00	
Directions to make Thermister Probe	$4.00	
Thermister calibration	$3.00	
Heats of Reaction	$4.00	
Heats of Reaction, Instructor's notes	$3.00	
Photochromic Kinetics	$4.00	
Photochromic Kinetics, Instr. notes	$4.00	
Directions to make AppleIIc Adapter Box	$4.00	
Dir. to make Commodore 64 Adapter Box	$4.00	
Homebrew hardware: Apple Interfacing	$2.00	
Beer's Law with the Blocktronic I	$3.00	
Kinetic study of thiosulfate in acid	$3.00	
Kinetic study of ferric and iodide ions	$3.00	
Cooling and heating curve	$3.00	
Simple heat of reaction	$3.00	
Change of phase in Glauber's salt	$3.00	
Photochromic kinetics II	$4.00	
Photochromic kinetics II, instr. notes	$3.00	
Universal Apple II+/IIe/IIc adapter box	$4.00	
Adapter Box for the IBM PC	$4.00	
Heats of Reaction using Hess' Law	$4.00	
Kinetic Study - persulfate & iodide ions	$4.00	
Molar mass of unknown substance	$4.00	

Quantum Technology
30153 Arena Drive
Evergreen, Colorado 80439
(303) 674 9651

Item	Price	Computer
Lab Pac I & LEAP Standard ADC System	$895.00	Apple
Lab Pac I & LEAP Advanced ADC System (25 experiments in physics, chemistry, life science, earth science)	$1275.00	Apple

Sci-Comp
(American Association of Physics Teachers materials)
P.O. Box 335
Blandenburg, Maryland 20710

Item	Price	Computer
Blue box (interface)	$50.00	Apple
Temperature probe	$11.00	
Light probe	$5.00	
Solid state relay	$35.00	
ADC Board	$32.50	Apple
DIP Extender(for game port 16 pin)	$16.00	Apple
pH measuring system	$40.00	
Kinematics of a student device	$35.00	Apple
Science Interfacing diskette 3.0	$20.00	Apple
Tutorial for teachers (manual and diskette to be used with the above equipment)	$20.00	Apple

Technical Education Resource Center
1696 Madison Avenue
Cambridge, Massachusetts 02138

Item	Price	Computer
Software for ultrasonic probe (Micromint supplies the major components)	$5.00	Apple

Tel-Atomic
P.O. Box 924
Jackson, Michigan 49204
(517) 783 3039

Item	Price	Computer
Vela II Multifunction Microcomputer (telatomic also carries the entire line of Harris sensors and the Champ interface listed under Merlan Co.)	$625.00	

Thornton Associates Inc.
1432 Main Street
Waltham, Massachusetts 02154
(617) 890 3399

Item	Price	Computer
Apple, IBM		
Apple IIe serial card	$95.00	Apple
Sensor Processor Interface	$795.00	Apple, IBM
Temperature probe	$75.00	Apple, IBM
Microphone probe	$63.00	Apple, IBM
Speaker	$76.00	Apple, IBM
Infrared light source	$58.00	Apple, IBM
Phototransistor	$60.00	Apple, IBM
Scope probe adapter for voltage	$56.00	Apple, IBM
Temperature software	$49.00	Apple, IBM
Sound software	$49.00	Apple, IBM
Motion (Light) software	$49.00	Apple, IBM

Thought Technology
2180 Belgrave Avenue
Montreal, Prov. of Quebec
Canada H4A 2L8
(514) 489 8251

Item	Price	Computer
Calmpute (galvanitic skin response)	$100.00	Apple
Temperature probe	$16.20	
Electomyograph measurement	$200.00	
Heart rate / blood volume pulse (each requires calmpute)	$200.00	

Vernier Software
2920 S.W. 89th Street
Portland, Oregon 97225
(503) 297 5317

Item	Price	Computer
Graphical Analysis III	$24.95	Apple
Precision Timer II	$39.95	Apple
Frequency Meter	$39.95	Apple
Temperature Plotter	$39.95	Apple
Voltage Plotter	$39.95	Apple
Apple II+/IIe Photogate Kit(3 gates)	$40.00	Apple
Microphone amplifier kit	$12.00	Apple
4 temperature probe system	$60.00	Apple
Voltage Input Unit	$35.00	Apple
Advanced Interfacing Board(A/D & D/A)	$225.00	Apple
Sample and Hold Amplifier Kit	$35.00	Apple
How to Build a Better Mousetrap & 13 other Science projects using the Apple	$24.95	Apple

2. Printer interfaces to Permit Graphics Printing from Apple Computers

Beagle Brothers, Dept. F
3990 Old Town Avenue, Suit 102C
San Diego, California 92110

Item	Price	Computer
Triple Dump (prints screen dumps from graphics that have been saved on disk)	$39.95	Apple

Orange Micro Inc.
1400 N. Lakeview Avenue
Anaheim, California 92807
(714) 779 2772

Item	Price	Computer
Grappler+ (printer interface that allows screen dumps from unprotected programs)	$99.00	Apple

Texprint
220 Reservoir Street
Needham Heights, Massachusetts 02194
(617) 449 5808
(800) 255 1510

Item	Price	Computer
Print-it (printer interface cards that allow instant screen dumps from any program)	$153.00	Apple
Save-it (saves graphs pictures to disk)	$29.95	Apple

Thirdware computer products
4747 N.W. 72nd Avenue
Miami, Florida 33166
(305) 592 7522

Item	Price	Computer
Fingerprint plus (printer interface cards that allow instant screen dumps from any program)	$149.00	Apple

3. Components for MBL Construction

Analog Devices
2 Technology Way
P.O. Box 280
Norwood, Massachusetts 02062
(617) 329 4700

Item	Price	Computer
Temperature sensor #AD590J	$4.30	

Measurements Group
P.O. Box 27777
Raleigh, North Carolina 27611
(919) 365 3800

Source of components for the construction of strain gauges. Strain gauge construction is an advanced project at a highly technical level.

Micromint Inc.
25 Terrace Drive
Vernon, Ct. 06066
871 6170

Item	Price	Computer
Ultrasonic Ranger T101 Apple (Major components only, preliminary software and assembly instructions available from TERC)	$60.00	Apple

Newark Electronics
116 Cottage Grove Road
Bloomfield, Connecticut 06002
(203) 243 1731

Item	Price	Computer
Fenwal thermistors (GA43P2 or GA45P2 or GA51P2)	$5.20	

Radio Shack
(local)

(source of parts and components for interface construction)

Item	Price	Computer
Phonoplug Adapter (#42-2436)	$2.59	
72" monitor cable (#42-2358)	$2.49	

(These can be used to display the output of one computer on more than one monitor in a class room situation)

4. Game Port Extenders for Apple Computers

Happ Electronics,Inc.
4640 Island View
Oshkosh, WI 54901
(414) 231 5128

Item	Price	Computer
Game socket extender I	$18.95	Apple
Game socket extender II	$24.95	Apple
(zero insertion force game port extenders)		

Scooter
746 Vermont Street
Palatine, Illinois 60067
(312) 359 5500
(800) 323 2727

Item	Price	Computer
Zero force twin port (game port extender)	$38.50	Apple

SCRG (Southern California Research Group)
P.O. Box 593
Moorpark, California 93020
(800) 635 8310

Item	Price	Computer
Paddle Adapple(game port extender)	$29.95	Apple
9-16 pin game port adapter	$14.95	Apple
16-9 pin game port adapter	$14.95	Apple

Vernier Software
2920 S.W. 89th Street
Portland, Oregon 97225
(503) 297 5317

Item	Price	Computer
Zero insertion force 16-pin extender	$16.00	Apple

APPENDIX D
MICROCOMPUTER-BASED LABORATORY BIBLIOGRAPHY

Journal Articles, Texts and Monographs

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ETC TARGETS, Educational Technology Center, 337
Gutman Library, Cambridge, Massachusetts 02138

HANDS ON!, Technical Education Research Centers, 1696
Massachusetts Avenue, Cambridge, Massachusetts 02138

PROJECT SERAPHIM NEWS, Project Seraphim, Department of Chemistry,
Eastern Michigan University, Ypsilanti, Michigan, 48197

VERNIER SOFTWARE NEWSLETTER, David Vernier, 2920
S.W.89th Street, Portland, Oregon 97225

Periodicals That Cover Apple Computers And MBL Applications

Apple Education News — 4 issues - free
20525 Mariani Avenue
Cupertino, California 95014

A PLUS — 12 issues - $24.95
P.O. Box 2964
Boulder, Colorado 80321

Classroom Computer Learning — - free
2451 East River Road
Dayton, OH 45439

inCider — 12 issues - $24.97
CW Communications/Peterborough
P.O. Box 911
Farmingdale, New York 11737

Nibble — 12 issues - $26.95
45 Winthrop Street
Concord, Massachusetts 01742

Science Teacher — 9 issues - $32.00
National Science Teacher Association
1742 Connecticut Avenue, N.W.
Washington, D.C., 20009

Physics Teacher — 9 issues - $35.00
Membership Department/Suite 101
American Association of Physics Teachers
5110 Roanoke Place
College Park, Maryland 20740

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* A Guide to Curriculum Development in Applied Mathematics: A Three-year Sequence for Non-college Bound Students, (Vol. 1 of 3, preliminary edition, 1986), 82 pp. $3.25
* Down to Earth Chemistry (for the Non-college Bound), 3 sample units, 1987, 60 pp. (free)
* A Review of Selected Microcomputer Software Packages with Lessons for Teaching Mathematics, Grades 8-12, 1987, 122 pp. $4.50
* A Guide to Computer Use by the Science Teacher, 1987 c., 70pp. $3.00